Electro-Optic Identification Research Program: Performance Prediction Model

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LONG-TERM GOALS

The overall goal of the Electro-Optic Identification (EOID) Research Program is to support the performance of EOID sensors transitioning to the fleet. EOID is used in the identification of Mine Like Objects (MLOs) and is a pressing need for Mine Countermeasures (MCM) operations. The EOID sensors include the Streak Tube Imaging LIDAR (STIL), which is transitioning to the AN/AQS-20/X and the WLD-1 (Remote Mine-hunting System) programs, and the Laser Line Scan (LLS), which is transitioning to the AN/AQS-14A(V1) program. Through these transitions, EOID will be a key element in implementation of Fleet plans for a robust organic MCM capability.

The EOID Research Program will begin to provide the tools to meet specific Fleet needs and capabilities, which include:

- Perform mission planning, real-time performance assessment, and post-mission analysis

- Flow down Fleet identification requirements to the system and operational parameters

- Develop Computer Aided Identification (CAI) algorithms to aid in the operator identification of mines

- Develop Autonomous identification capability for future systems

- Assess and evaluate alternate designs for future systems

OBJECTIVES

The primary objective of this phase of the program is to validate existing performance prediction and simulation models and to develop and test Automatic Target Recognition Algorithms (ATR) for electro-optic identification (EOID) systems. In addition, some secondary objectives include:

- Conduct a performance assessment of the existing EOID sensors

- Develop and test the Through the Sensor Environmental Characterization (TSEC) capabilities for EOID sensors

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14. ABSTRACT
The overall goal of the Electro-Optic Identification (EOID) Research Program is to support the performance of EOID sensors transitioning to the fleet. EOID is used in the identification of Mine Like Objects (MLOs) and is a pressing need for Mine Countermeasures (MCM) operations. The EOID sensors include the Streak Tube Imaging LIDAR (STIL), which is transitioning to the AN/AQS-20/X and the WLD-1 (Remote Mine-hunting System) programs, and the Laser Line Scan (LLS), which is transitioning to the AN/AQS-14A(V1) program. Through these transitions, EOID will be a key element in implementation of Fleet plans for a robust organic MCM capability.

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- Develop Real-Time Image Processing Algorithms and Displays (RTIP & D)

APPROACH

To collect the data required for this program, an existing towed body was modified to house the three laser identification systems in one unit to allow simultaneous operations under identical environmental conditions. The three laser identification systems included the Areté Associates Streak Tube Imaging LIDAR (STIL) system, the Northrop Grumman Laser Line Scan (NG-LLS) system, and the Raytheon LLS (R-LLS) system as shown in Figure 1.

Figure 1 Towed Body at the Dock

The system was towed through a field in the Gulf of Mexico off Panama City, Florida comprised primarily of optical targets with some sample mine-like objects while image data from each of the three EOID systems was collected. Ocean optical properties were measured during the test and the operations area was surveyed so that clutter objects were known. This data was then distributed to all participating organizations for use in performance prediction model validation, ATR development, and performance assessment.

IMPERSonator, the CSS-developed optical model, models optical propagation using Monte Carlo techniques to predict the performance of an EOID system under varying environmental conditions. This allows the results to be based on the inherent optical properties (IOPs) of the water, including the beam absorption, scatter, and attenuation coefficients (a, b, and c), and the scattering phase function $\beta(\vartheta)$. It avoids limitations associated with small angle scattering approximations. In addition, Monte Carlo methods are used to track time-of-flight of the photons. This time resolution can be used to model time-of-flight aspects of the STIL sensor.

Model validation will be accomplished using the test data acquired under this program in FY01 and FY02.

WORK COMPLETED

Modifications were made to the towed body for acceptance of the three EOID sensors that were subsequently integrated into the towed body system. Data collection was conducted in the Gulf of

Mexico off of Panama City, Florida in approximately 60-70 feet of water. Data was collected from a target field about 300 feet in length consisting of 24 technical targets, 12 Mine-like objects, clutter, and a 12-foot stepladder. Data collection operations were conducted over a two-week period and consisted of multiple passes per day over the same target field at varying altitudes that were based on optical property measurements taken before the start of each day. Data was collected in both day and nighttime conditions at speeds between 5 and 10 knots. Daily, data were archived, processed and browsed to determine utility.

Initial models of the STIL and LLS sensors have been produced. The STIL model covers a pulsed fan beam architecture sensor. It is a full 2D imaging model that includes treatment of signal and of backscatter and blur/glow/forward scatter noise, detected power levels, and conversion to photoelectrons and "digital counts". A partial 3D imaging model, capable of treating the temporal response of the system, has also been implemented. It is anticipated that this 3D model will be extended in FY02. The LLS model is a full 2D imaging model that includes treatment of signal and of backscatter and blur/glow/forward scatter noise, detected power levels, and conversion to photoelectrons and "digital counts". It also includes initial treatment of solar ambient light noise. While this is a model for generic LLS sensors, most care has been devoted to fidelity for the Raytheon LLS sensor (EOID).

These initial models have been used to produce initial performance envelope predictions for the STIL and Raytheon LLS (R-LLS) sensors. Additionally, they have been used to produce simulated imagery of MLOs and clutter under a variety of environmental conditions.

In anticipation of the model validation work to be performed in FY02, image analysis tools have been written for the STIL and R-LLS sensor data. The STIL program will display the spatial image for any time/range band, the spatial image formed by summing the return for each time/range bin, the image formed from the value of the peak bottom return for each spatial pixel, or the image formed from the time/range band (bin) number corresponding to the peak bottom return. Using these tools, analysis of the FY-01 test data has been initiated.

RESULTS

The EOID Gulf of Mexico Test provided the data required for model validation with a small set useful for ATR development. All three sensors were successfully deployed and operated in one underwater TB and testing verified that the sensors operated functionally under towing conditions. Initial results from browsing the data showed that each sensor performed optimally based on the altitude and water conditions. Data was successfully captured for seven full days and two partial days of data collection under a variety of altitudes and environmental conditions. Some optical cross-talk was noted; however, post-mission processing proved sufficient to remove these effects.

During the course of the year, prior to validation efforts, preliminary modeling results were obtained. These results are qualitatively presented here. For the STIL sensor the primary adjustable parameter is the slit width. The model has shown that varying the slit width has two primary (but related) impacts. First, increasing the slit width leads to detection of greater numbers of photons. Second, the additional photons detected are primarily blur/glow/forward scatter photons, and, to a lesser extent, backscatter photons. In any case, the additional photons detected contain little or no detailed information about the scene being imaged. Accordingly, in order to get the sharpest image it would be desirable to operate with minimal slit width. However, if the slit width is reduced too far there may be insufficient

numbers of photons detected to locate the bottom in the temporal return from the laser pulse. This means that in turbid water and/or at extended ranges there is a trade-off relationship between these two competing effects, as illustrated in Figure 2. An increase in the laser power would extend the useful operating range by allowing the bottom return to be resolved at narrower slit widths. Because of the pulsed nature of the STIL sensor, the STIL sensor is unaffected by the solar ambient light.

For Laser Line Scan sensors, the primary adjustable parameters are the Upper Imaging Range (UIR) and the Lower Imaging Range (LIR). Varying the UIR and LIR results in impacts in several quantities, including blur/glow/forward scatter noise, backscatter noise, solar ambient light noise, and the quantity of photons detected. In general it is desirable to set the UIR and LIR to tightly bracket the physical range over the entire scan line. As the UIR and LIR are adjusted to more loosely bracket the physical range, the magnitude of blur/glow/forward scatter noise and backscatter noise increase, degrading the quality of the image. In addition, in shallow, turbid water solar ambient light can become the factor limiting the performance of LLS sensors. This effect could be ameliorated either by increasing the laser power, or by going to a pulsed/gated laser line scan architecture.

IMPACT/APPLICATIONS

The long-term results obtained by this project are expected to support the current transitions of EOID to the fleet, and to lay a firm foundation for the development of next generation AEOID sensors designed for next generation organic platforms.

TRANSITIONS

Of more immediate impact, however, was the additional operating time logged by the sensors under very stressing conditions. The system developers saw water clarity conditions that have not been encountered – or considered – in earlier efforts. These conditions had some unpleasant consequences for post-mission processing routines in particular and forced a re-evaluation of environmental impact. All system developers also learned much about the strengths and weaknesses of their particular sensor and have begun looking at options for improvement.

RELATED PROJECTS

The ENVI/C++ data analysis tools developed to assist the model validation effort were derived from similar data analysis tools developed in FY01 for the CoBOP project.
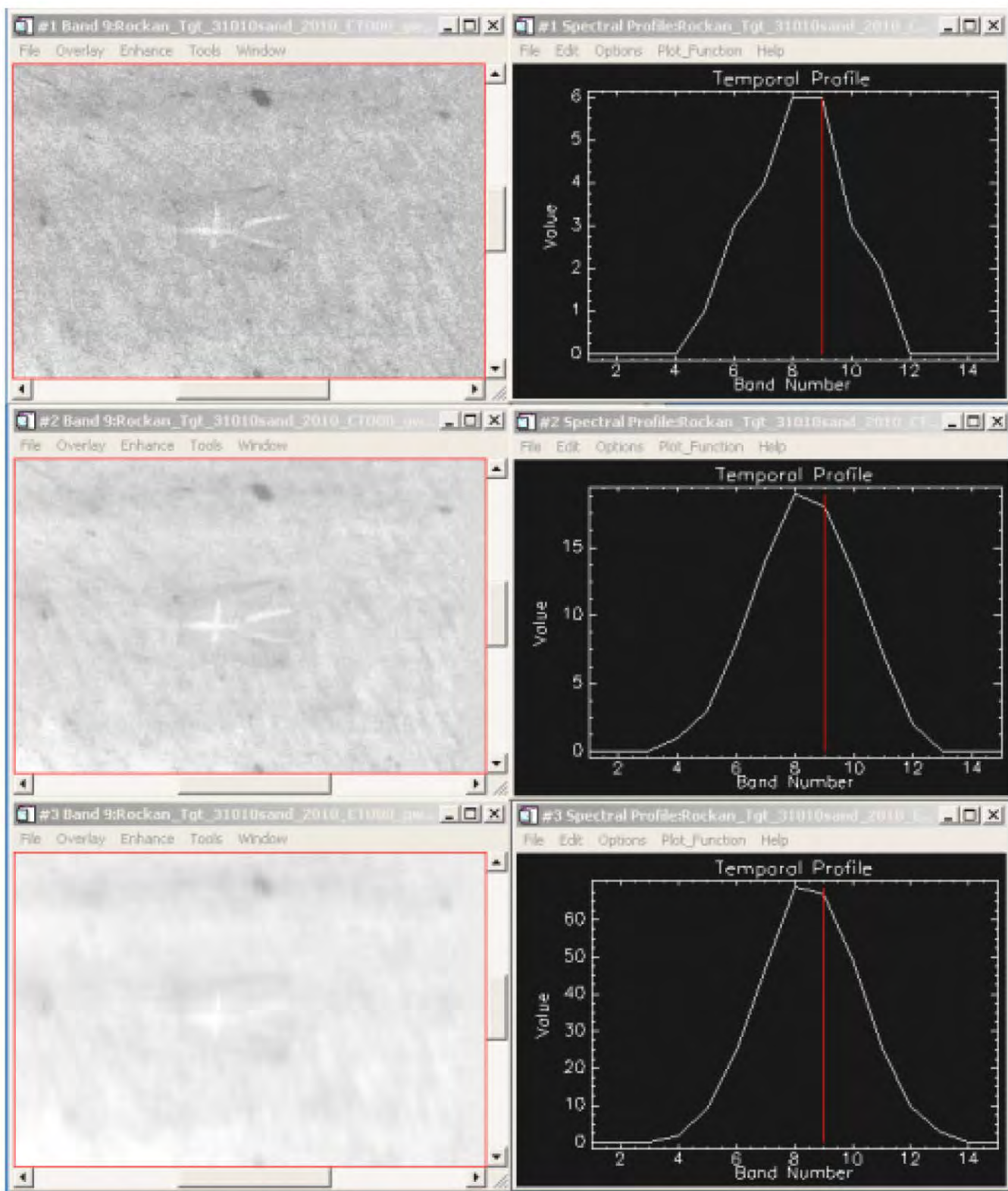
Figure 2 Modeling results of the same scene at 3 different receiver slit widths The top line shows the "peak signal strength" image and the temporal profile of the return with a narrow receiver slit width. The image is relatively sharp, but grainy due to the low signal strength. The bottom two lines show results with successively larger slit widths, yielding more blurry but less grainy images.

REFERENCES

EOID Data Management Plan, 4 May 2001.

Model Validation Plan, 30 July 2001.

EOID Research Program Gulf of Mexico Data Collection Plan, 25 July 2001.

EOID Automatic Target Recognition (ATR), 1 May 2001.